WNER'S GUIDE

Sustaining Forest Soil Productivity

United States Department of Agriculture

Forest Service
February 1994

PREPARED BY:
Pacific Northwest Research Station

INTRODUCTION

AS A WOODLAND OWNER, you can influence whether management activities will adversely affect the productivity of your woodland resources. Loss of soil productivity can happen anytime forest harvest or site preparation activities occur (Amaranthus and others 1985, Froelich 1979, Minore 1986). Fortunately, you can prevent adverse impacts with a working understanding of the role of forest soil in a productive forest and careful planning and implementation of forest activities.

SOIL

SOILS ARE CRITICAL to forest productivity and provide 24 of the 26 elements required by plants and animals (carbon and oxygen are not provided through soil). Soils are important not only because of their immediate effect on the productivity of plants and animals but also because they are the storehouse that supports future forests. In a very real way, soils can be viewed as a factory that, when working correctly, can produce productive, healthy forests indefinitely.

COMPACTION

Forest soil is a mixture of mineral particles, air, water, living and dead organic matter, and nutrients. Surprisingly, only about half of the contents of soil are solids; the rest is pore space containing air and water (fig. 1, flap). Soil is compacted when the areas between soil particles and clods are pushed closer together, thereby reducing pore space. Soil porosity influences forest productivity directly by influencing the movement of water and oxygen into the soil and the penetration, growth, and distribution of roots.

Soil is most easily compacted when machinery applies ground pressure and vibration to the soil during forest harvest operations and mechanical site preparation (Adams 1983). The resultant packing of mineral particles and clods reduces the pore space (good sites) for root growth, soil drainage, and aeration and can reduce forest productivity for decades. You can see this effect by examining your soil structure, which develops a platey characteristic when compacted (fig. 2, flap). Compaction also greatly increases the risk of erosion problems. Water movement into and through a compacted soil is reduced, which increases the risk of water runoff.

Research and monitoring have improved the ability to identify operations that degrade woodland productivity and ways to minimize adverse effects. Soils are our most fundamental source of wealth, our basic resource. Your practices can protect the productive potential of soils and are a good investment for both current and future generations.

The purpose of this publication is to increase your understanding of the kinds of impacts woodland activities can have on soil. It also provides ideas for minimizing these impacts and maintaining a healthy and productive forest.

The Basic Resource

across the soil surface. Concentrated runoff can move soil particles off-site, decrease water quality, and damage fish habitat. Fortunately, you have many options for avoiding compaction on your land; many are described in this brochure.

SOIL FERTILITY

Soil fertility is determined by the amount and availability of nutrients at a given place (site). In the Pacific Northwest, most available nutrients are in the surface organic litter, duff layers, and the upper mineral layer of soil, an average depth of 12 inches west of the Cascade Range. East of the Cascades and in the Klamath Mountain region, this layer can be shallower: the top 5 inches or less. Erosion, severe fire, and mechanical operations can displace some of this layer and result in the loss of nutrients and woodland productivity (Atzet and others 1990, Grier 1975).

Soil is full of beneficial soil organisms profoundly affecting forest site productivity; for example, mycorrhizal fungi (fungi that form a close and mutually beneficial relation with the roots of plants; fig. 3A, on flap) and nitrogen-fixing organisms (specialized soil microbes that change atmospheric nitrogen into chemical forms usable by plants; fig. 3B, on flap). These organisms capture and take in nutrients and water, protect roots against diseases, and promote soil structure. Severe disturbance, such as intense fire or the piling and removing of surface organic matter, can reduce or eliminate beneficial soil organisms (Amaranthus and others 1990). Impacts on these beneficial organisms are minimized when forest practices emphasize retention of organic matter and rapid regeneration.

Figure 1—Electron micrograph of typical forest soil in the Pacific Northwest shows abundant pore spaces.

Figure 2—(A) Soil compaction often results in platey structure. (B) Upper mineral layers of productive forest soils typically have granular structure (from Adams 1983).

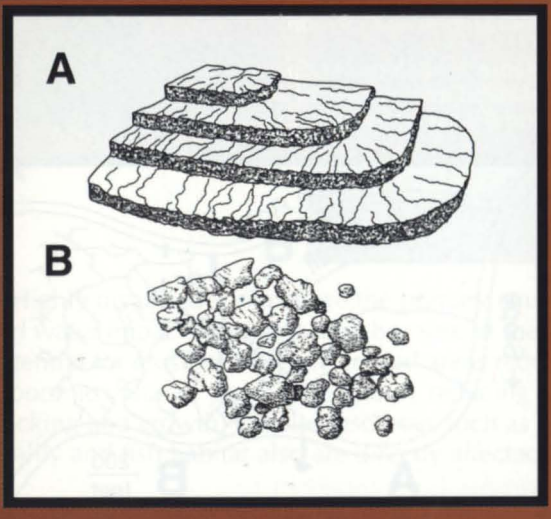


*Figure 3—(A) White threadlike filaments of mycorrhizal fungi extending from roots of pine seedling capture moisture and nutrients and improve growth. (B) Nodules on red alder (*Alnus rubra *Bong.) contain nitrogen-fixing organisms that convert nitrogen in the atmosphere to an organic form usable by plants.*

A

B

Figure 4—Productive forest soil.

CHARACTERISTICS OF HIGHLY PRODUCTIVE SOILS

Highly productive soils have certain characteristics that positively influence the growth of plants (fig. 4).

Porosity—Promotes aeration, water movement into soil, root growth, and distribution.

Loose, granular structure—Promotes drainage and enhances the ability of roots and mycorrhizal fungi to access nutrients and water.

Abundant surface organic matter—Increases nutrient storage and release and is important habitat for roots and beneficial soil organisms that promote plant growth.

Figure 5—Degraded forest soil.

CHARACTERISTICS OF DEGRADED SOILS

Degraded soils have certain characteristics that negatively influence the growth of plants (fig. 5).

Compaction—Decreases pore space, air, and water exchange and root penetration. Low porosity and poor drainage increase the likelihood of infection by root diseases.

Hard, platey structure—Impedes drainage, root and mycorrhizal penetration, and distribution.

Eroded surface layer—Reduces organic matter, nutrient levels, soil structure, and populations of beneficial soil organisms. Off-site erosion can damage fish habitat and degrade water quality.

Where to Get More Help

On-site technical advice and planning—
USDA Soil Conservation Service, county offices
Oregon Department of Forestry, county offices
Washington Department of Natural Resources (DNR)
Forest Landowner Assistance Program, P.O. Box 47046, Olympia, WA 98504

Educational materials and programs—
Oregon State University Extension Service, county offices
Washington State University Cooperative Extension Service, county offices

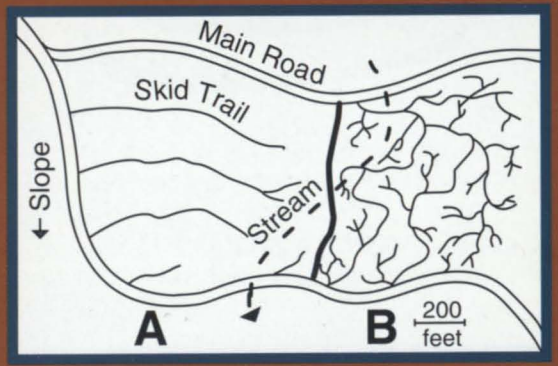
Financial assistance—
Federal cost-sharing programs can reimburse forest landowners for most of the costs associated with forest improvement projects. Contact your local USDA Agricultural Stabilization and Conservation Service Office (ASCS).

WHAT YOU CAN DO

- Keep soil and litter in place especially in extremely steep areas.
- Avoid operations when soils are excessively wet.
- Keep water in natural drainages.
- Use crossdrains, dips, or culverts to control the movement and concentration of water.
- Reduce the area covered by skid trails, roads, and landings through careful planning (fig. 7). Use flagging to identify skid trails before logging. The area covered in skid trails should be 15 percent or less of the total area when a tractor (that is, rubber-tired skidder, crawler tractor) is used for logging.
- Use machinery on frozen soil or snow to decrease compaction.
- Avoid frequent use of machinery, especially where machinery fails to use existing skid trails, roads, or landings.
- Rapidly revegetate areas with high erosion potential.
- Till compacted areas with high erosion potential.
- Till compacted areas to increase soil porosity and drainage.

Figure 6—Right. (A) Erosion and sedimentation can cause both on-site and off-site impacts. (B) Suspending logs during harvesting decreases risk of compaction and erosion.

Figure 7—Below. (A) Carefully planned minimal use of skid trails and (B) excessive use of skid trails.



Harvesting

HARVEST and ROAD CONSTRUCTION are important tools for achieving the objectives of many woodland owners. However, harvest and roading activities can have long-term adverse effects on soil productivity when improperly applied. For example, main roads, skid roads and landings can reduce soil productivity through excess:

- Scalping (removing vegetation including the roots near the surface) and displacement of organic and upper mineral soil layers.
- Consuming space that could grow trees and other plants.
- Compacting by heavy equipment or dragging of logs.
- Exposing of infertile subsoils.
- Channeling water and causing erosion.

Research indicates that compaction rapidly increases with the first few passes of heavy machinery (Froelich 1979). On most forest soils in the Pacific Northwest, compaction decreases tree growth. Measurements of commercially important conifer species indicate that height and diameter growth are lowered by 5 to 50 percent in compacted areas. Significant growth reductions can result from compaction, thinning and final harvest operations. The effects can last for decades.

A

B

Highly disturbed surfaces are the primary cause of soil and water impacts on forest land because of their high potential for erosion. Severely eroded areas reduce the economic value of your woodland by reducing tree stocking and growth. Off-site resources such as water quality and fish habitat also are directly affected (fig. 6).

Site Preparation

PREPARATION OF YOUR FOREST SITE can greatly aid forest establishment. Site preparation most often is used to improve seedling survival and growth, reduce risk of catastrophic wildfire, provide planting areas for trees, create a mineral seedbed for natural regeneration, and reduce competing vegetation. Your site preparation activities also can reduce soil productivity when:

- Mechanical scarification and windrowing (pushing logging slash into rows) remove the organic layer and upper mineral soil, and cause widespread compaction (fig. 8).
- Severe slashburning reduces fertility by consuming surface organic matter, releasing nitrogen into the air, reducing surface infiltration, and causing increased erosion (fig. 9).

Your site preparation activities should protect important surface layers of soil. Nitrogen, an important nutrient influencing forest productivity, is significantly higher in the surface soil layer compared to subsoil layers (Powers 1988).

WHAT YOU CAN DO

- Avoid soil-disturbing activities on steep slopes and erosive soils.
- Hand-pile fuel concentrations to minimize area impacted by ground-based machinery.
- Avoid mechnical windrowing of material to leave topsoil in place.
- Operate heavy machinery during the dry season.
- Operate machinery along the contour on sloping ground.
- Burn when soils are wet.
- Keep burn intensities low and durations short.

Sustained Soil Productivity

YOUR WOODLAND ACTIVITIES, especially those related to harvesting and site preparation, can maintain soil productivity. If you plan and implement your forest activities properly, you can minimize problems and maintain the quality and value of your forested land. Productive forest soils take thousands of years to develop; protecting this basic resource is a sound investment both now and in the future.

Photos at left:

Figure 8—Windrowing can result in excessive soil disturbance, organic matter removal, and compaction.

Figure 9—Severely burned areas have greater risk of nutrient loss and erosion.

REFERENCES

Adams, P.W. 1983. Soil compaction on woodland properties. Exten. Circ. 1109. [Corvallis, OR]: Oregon State University Extension Service.

Amaranthus, M.P.; Molina, R.; Trappe, J.M. 1990. Long-term forest productivity and the living soil. In: Perry, D.A., ed. Maintaining long-term forest productivity in the Pacific Northwest forest ecosystem. Portland, OR: Timber Press. Chapter 3.

Amaranthus, M.P.; Rice, R.M.; Barr, N. [and others]. 1985. Logging and forest roads related to increased debris slides in southwest Oregon. Journal of Forestry. 83(4): 229-233.

Atzet, T.; Powers, R.F.; McNabb, D.H. [and others]. 1990. Maintaining long-term forest productivity in southwest Oregon and northwest California. In: Perry, D.A., ed. Maintaining long-term forest productivity in the Pacific Northwest forest ecosystem. Portland, OR: Timber Press. Chapter 8.

Froelich, H.A. 1979. Soil compaction from logging equipment: effect on growth of young ponderosa pine. Journal of Soil and Water Conservation. 34: 276-278

Grier, G.C. 1975. Fire effects on nutrient distribution and leaching in a coniferous ecosystem. Canadian Journal of Forest Research. 5: 599-607.

Minore, D. 1986. Effects of site preparation on seedling growth. Res. Note PNW 452. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Powers, R.F. 1988. Nitrogen mineralization along an altitudinal gradient: interactions of soil temperature, moisture and substrate quality. Forest Ecology and Management. 9: 45-56

AUTHOR

DR. MICHAEL P. AMARANTHUS is team leader of the Long-term Ecosystem Productivity program for the Pacific Northwest Research Station, P.O. Box 3890, Portland, OR 97208.

Pacific NorthwestResearch Station
P.O. Box 3890
Portland, OR 97208

* U.S. Goverment Printing Office: 1994-584-268